DTU Library

640 Gbit/s time-division add-drop multiplexing using a non-linear polarisation-rotating fibre loop

Mulvad, Hans Christian Hansen; Galili, Michael; Grüner-Nielsen, Lars; Oxenløwe, Leif Katsuo; Clausen, Anders; Jeppesen, Palle

Published in:
European Conference on Optical Communication

Link to article, DOI:
10.1109/ECOC.2008.4729220

Publication date:
2008

Document Version
Publisher's PDF, also known as Version of record

640 Gbit/s Time-Division Add-Drop Multiplexing using a Non-Linear Polarisation-Rotating Fibre Loop

H.C.H. Mulvad (1), M. Galili (1), L. Grüner-Nielsen (2), L.K. Oxenløwe (1), A.T. Clausen (1), and P. Jeppesen (1)
1 : Department of Photonics Engineering, Technical University of Denmark, DK-2800 Kgs. Lyngby, Denmark
e-mail: hchm@com.dtu.dk
2 : OFS Fitel Denmark ApS, Priorparken 680, DK-2605 Brøndby, Denmark

Abstract

We report the first demonstration of error-free 640 Gbit/s time-division add-drop multiplexing, performed by non-linear polarisation-rotation using a loop with a polarisation-maintaining HNLF.

Introduction

Time-division add-drop multiplexing (TADM) is the switching functionality where data pulses are extracted and replaced in a serial data stream. A possible application is in optical time-division multiplexed (OTDM) systems, where the data signals are formed by bit-interleaving narrow-pulse, identical-wavelength data channels at a low base rate (e.g. 10 Gbit/s), enabling aggregate bitrates currently up to 640 Gbit/s. Fibre-based switches are the most promising candidates for TADM at ultra-high bitrates, since they are based on the Kerr non-linearity with a response time of a few fs, which prevents data-pattern dependence. Fibre-based TADM switches have previously been demonstrated using Kerr shutters at 160 Gbit/s [1,2], and with non-linear optical loop mirrors at 160 Gbit/s [3] and 320 Gbit/s [4].

Here, we report on the first demonstration of TADM of a 640 Gbit/s OTDM data signal, using a new non-linear polarisation-rotating loop (PRL), which is a looped version of the Kerr shutter, containing a 94 m elliptical core polarisation-maintaining highly non-linear fibre (PM-HNLF) [5]. This switch makes it possible to simultaneously drop a data-channel and clear the corresponding bit-slot, enabling a new channel to be coupled into the output OTDM data. Bit-error rate (BER) measurements show error-free performance, including a low penalty imposed on the added channel.

Principle and experimental set-up

The experimental set-up is shown in Fig. 1 (a), covering the TADM with separate drop-operation (*DROP*) and add-operation (*ADD*), followed by a demultiplexer (*DEMUX*). The drop-operation is performed using the PRL, followed by a polarising beam splitter (PBS2). The PRL is formed by a loop connecting the two outputs of PBS1. The entire loop is built from polarisation-maintaining (PM) components, which results in increased stability and avoids an internal polarisation controller. All signals propagate along the slow axis. High-intensity 10 GHz control pulses are coupled into the slow axis of the loop via a PM 3 dB coupler, and are blocked after the PM-HNLF by a 15 nm PM bandpass filter (BPF). The 94 m PM-HNLF has dispersion 0.13 ps/(nm·km) and slope 0.027 ps/(nm^2·km) at 1550 nm, and non-linear coefficient $\gamma \sim 10\ W^{-1}km^{-1}$.

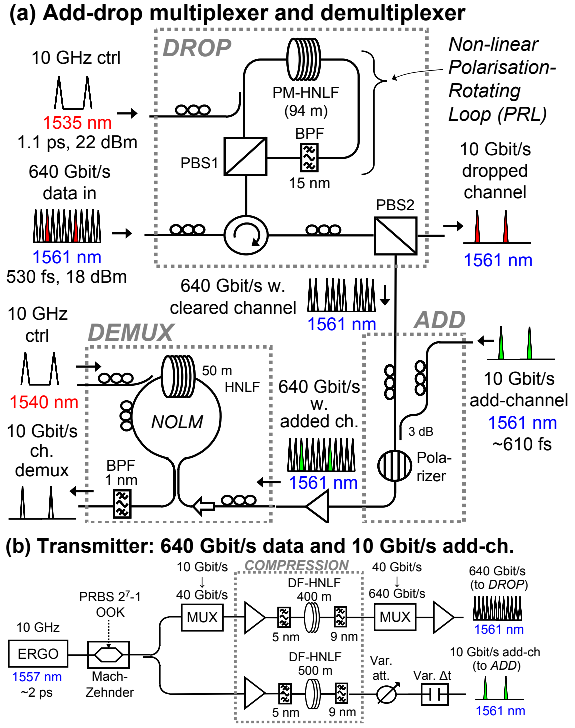

Figure 1: Experimental set-up.

The working principle of the PRL is briefly described in the following. The polarisation of the incoming OTDM signal is set to a linear state at a 45˚ angle to the principal axis of PBS1. It is then split into two field-components $E^{\parallel}$ and $E^{\perp}$ with equal amplitude, with $E^{\parallel}$ propagating in the clockwise (c-w) direction of the PRL, and $E^{\perp}$ in the counter-clockwise (c-c-w) direction. A phase-shift of π is then imposed on the $E^{\parallel}$-component of the channel to be dropped (target channel), achieved by cross-phase modulation (XPM) from the control pulses inside the PM-HNLF. When $E^{\parallel}$ and $E^{\perp}$ are recombined again at PBS1, the XPM-induced π-phaseshift on the $E^{\parallel}$-component of the target ch causes its polarisation-state to be rotated by 90˚ *compared* to the other data-channels. This enables the target ch to be completely extracted by

PBS2, which simultaneously clears the corresponding bit-slots in the OTDM signal (*DROP*). This allows a 10 Gbit/s add-channel to be coupled into the OTDM signal by a 3 dB coupler, followed by a polarizer to ensure identical polarisations (*ADD*). After the add-operation, the OTDM signal is demultiplexed (*DEMUX*) in a non-linear optical loop mirror (NOLM) for BER characterisation.

The transmitter for data pulses is shown in Fig. 1 (b). A 10 GHz erbium glass oscillating laser (ERGO) emits ~2 ps pulses at 1557 nm, which are data-modulated by on-off keying with a 2^7-1 PRBS pattern. The resulting 10 Gbit/s pulses are split and used to generate both the 640 Gbit/s data and the 10 Gbit/s add-channel. The 640 Gbit/s data are generated using 2^7-1 PRBS maintaining delay-line multiplexer stages (MUX), with an intermediate pulse compressor. The 10 Gbit/s add-channel pulses are compressed, followed by a variable attenuator and time-delay to ensure the correct amplitude and timing before the add-operation. Control pulses are obtained from another 10 GHz ERGO laser at 1542 nm (synchronised by the 1557 nm ERGO). These pulses are compressed, split and then separately BPF-filtered and amplified before being used as control for the PRL and NOLM (not shown). All pulse compressors are based on chirping and spectral broadening by self-phase modulation in a (negative) dispersion-flattened HNLF (DF-HNLF). All relevant pulse FWHM widths, wavelengths and average powers are shown in Fig. 1, and pulse characterisations are found in Fig. 2 (a) and (b).

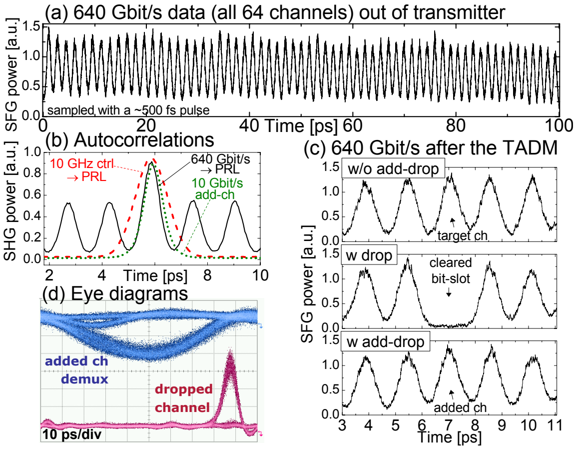

Figure 2: Pulse characterisations. (a), (c) cross-correlations, (b) autocorrelations, (d) eye diagrams.

Results

The add-drop operation is successful with error-free performance. Fig. 2 (c) shows cross correlations of the 640 Gbit/s data after the TADM. The top trace is without (w/o) add-drop operation. When the PRL ctrl pulses are on, the target ch is dropped at PBS2, leaving a cleared bit-slot (middle trace), into which the add-ch is then coupled (bottom trace). Fig. 2 (d) shows simultaneously open eye diagrams for both the dropped and demultiplexed added ch.

Fig. 3 shows the BER measurements. The 640 Gbit/s data are demultiplexed in two situations: with add-drop operation (w add-drop), and w/o add-drop operation, corresponding to the bottom and top traces of Fig. 2 (c). In Fig. 3 are shown BER curves for the target/added channel (b), its left (a) and right (c) neighbour channels. Fig. 3 (e) shows the obtained sensitivities of the target/added ch and 8 neighb. channels. The corresponding add-drop induced penalties are shown in Fig. 3 (f). The added ch suffers only a 1.1 dB penalty compared to the target ch. The left neighb. suffers a 2.3 dB penalty, which is mainly attributed to a small asymmetric pedestal of the added ch, and not the switching in the PRL. This penalty can thus be avoided by using e.g. a pedestal-suppression technique. The right neighb., as well as the remaining channels are practically unaffected, with penalties < 0.4 dB. The BER performance of the dropped ch. is error-free with a sensitivity of -32.1 dBm, as shown in Fig. 3 (d).

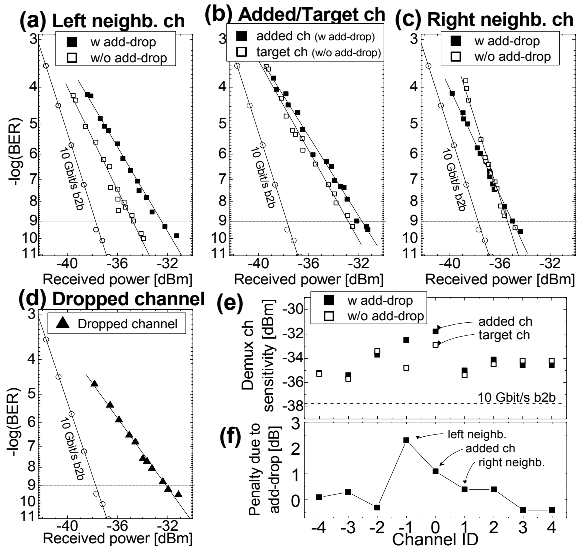

Figure 3: BER measurements

Conclusions

We have demonstrated time-division add-drop multiplexing at the record-high bitrate of 640 Gbit/s, using a new non-linear polarisation-rotating loop with a PM-HNLF. BER measurements showed error-free performance with only 1.1 dB add-drop penalty on the added channel.

References

1. C. Schubert et al OFC'05 (2005), paper OThN2
2. J.H. Lee et al Optics Express, Vol. 13 No. 18 (2005), pp. 6864-6869
3. E.J.M. Verdurmen et al ECOC'05 (2005), Th 3.1.7
4. H.C.H. Mulvad et al OFC'07 (2007), paper OTuI5
5. L. Grüner-Nielsen et al subm. to ECOC'08 (2008)

978-1-4244-2228-9/08/$25.00 (c) 2008 IEEE